

**CLAIMS**

We claim:

1. A method of processing seismic data generated by a seismic vibrator comprising the steps of
  - 5 (a) measuring a signal related to the vibrator motion;
  - (b) computing a vibrator signature for said measured vibrator motion signal;
  - (c) specifying a desired seismic data processing impulse response, wherein the high and low frequency portions of an amplitude spectrum of said impulse response taper to zero at a rate faster than does the high and low frequency portions of  
10 an amplitude spectrum of said vibrator signature;
  - (d) computing a deconvolution filter from the ratio of the desired impulse response and the computed vibrator signature;
  - (e) processing said seismic data using said deconvolution filter.
- 15 2. The method of claim 1, wherein said vibrator motion signal is the vibrator ground force signal.
3. The method of claim 1, wherein said vibrator motion signal is approximated by a vibrator pilot signal.
4. The method of claim 1, wherein small values of an amplitude spectrum of said  
20 impulse response are set equal to a threshold value.

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5. The method of claim 1, wherein small values of an amplitude spectrum of said impulse response are set less than a threshold value.
6. The method of claim 1, wherein the vibrator signature is computed from the time derivative of said ground force signal.
- 5 7. The method of claim 1, wherein said computation of said deconvolution filter involves an iteration in which zero phase and minimum phase impulse responses are analyzed to determine the suitability of said deconvolution filter to process high and low frequency data content in said seismic data.
8. The method of claim 1, wherein a plurality of seismic vibrators is used, and a  
10 resulting matrix of vibrator signatures is inverted and used to determine said deconvolution filter.
9. The method of claim 1, wherein a small amount of pre-whitening noise is added to all frequency values of an amplitude spectrum of said impulse response
10. The method of claim 1, wherein a plurality of vibratory sources are used to  
15 generate seismic data and a plurality of detectors are used to record the seismic data, wherein each vibrator is excited with a frequency sweep.
11. The method of claim 10 wherein a full solution involving all components of the matrix is generated by using one filter for all sweeps in a fully coupled derivation of the full matrix solution.
12. The method of claim 1 wherein the frequency sweep increases linearly in time.
13. The method of claim 1 wherein the frequency sweep decreases linearly in time.

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14. The method of claim 1 wherein the frequency sweep is a nonlinear sweep
15. The method of claim 1 wherein the frequency sweep is a random sweep
16. The method of claim 10 wherein different vibrators are energized by different sweeps which are phase encoded.
- 5 17. The method of claim 10 wherein different vibrators are energized by sweeps in which one vibrator a time is energized by a sweep with a 90 degree phase rotation relative to the phases of the other vibrators
18. The method of claim 10 wherein multiple sweeps are used and the sweeps include phase rotations of  $360/N$  degrees where N is an integer.
- 10 19. The method of claim 17 wherein multiple sweeps are used and the sweeps include phase rotations of  $360/N$  degrees where N is an integer.
20. The method of claim 10 wherein the different vibrators are energized by sweeps covering different frequency ranges at different times.
21. The method of claim 10 wherein the different vibrators are energized by  
15 sweeps which start at different times.
22. The method of claim 1 wherein the location of the detectors is selected from the group comprising detectors on the surface of the earth, detectors suspended in the water, detectors on the water bottom, detectors in a wellbore, and any combination thereof.
- 20 23. The method of claim 10 further comprising:

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(a) separating the data from each vibrator into individual records for each source location;

(b) applying static corrections and differential normal moveout (NMO) correction to each source location;

5 (c) summing the data for each source location.

24. The method of claim 10 further comprising (a) separating the data from each vibrator into individual records for each source location; (b) constructing supergathers to improve the noise separation techniques, and (c) summing the data for each source location

10 25. The method of claim 10 further comprising separating the data into bins at small common depth point intervals and migrating the data thereby improving imaging and focusing.

26. A method of processing seismic data generated by at least two seismic vibrators with a number of sweeps at least equal to the number of vibrators  
15 comprising the steps of

(a) measuring a vibrator motion signal for each vibrator;

(b) measuring the seismic signal;

(c) computing a vibrator signature for said measured vibrator motion signal;

20 (d) specifying a desired seismic data processing impulse response, wherein the high and low frequency portions of an amplitude spectrum of said impulse response taper to zero at a rate faster than does the high and low frequency portions of an amplitude spectrum of said vibrator motion signal;

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(e) computing a deconvolution matrix in the frequency domain that separates the earth response for each vibrator and replaces the individual vibrator signatures with the desired impulse response;

(f) processing said seismic data and separating the data according to the  
5 individual vibrators using said deconvolution matrix.

27. The method of claim 26, wherein said vibrator motion is the vibrator ground force signal.

28. The method of claim 26 wherein said vibrator motion is approximated by a vibrator pilot signal.

10 29. The method of claim 26, wherein small values of an amplitude spectrum of said impulse response are set equal to a threshold value.

30. The method of claim 26, wherein small values of an amplitude spectrum of said impulse response are set less than a threshold value.

15 31. The method of claim 26, wherein the vibrator signature is computed from the time derivative of said ground force signal.

32. The method of claim 26, wherein said computation of said deconvolution filter involves an iteration in which zero phase and minimum phase impulse responses are analyzed to determine the suitability of said deconvolution filter to process high and low frequency data content in said seismic data.

20 33. The method of claim 26, wherein a small amount of prewhitening noise is added to all frequency values of an amplitude spectrum of said impulse response

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34. The method of claim 26 wherein the frequency sweep increases linearly in time.
35. The method of claim 26 wherein the frequency sweep decreases linearly in time.
- 5 36. The method of claim 26 wherein the frequency sweep is a nonlinear sweep.
37. The method of claim 26 wherein the frequency sweep is a random sweep.
38. The method of claim 26 wherein different vibrators are energized by sweeps which are phase encoded.
39. The method of claim 26 wherein different vibrators are energized by sweeps in  
10 which one vibrator a time is energized by a sweep with a 90 degree phase rotation relative to the phases of the other vibrators
40. The method of claim 26 wherein multiple sweeps are used and the sweeps include in any order of phase rotations of  $360/N$  degrees where  $N$  is an integer.
41. The method of claim 39 wherein multiple sweeps are used and the sweeps  
15 include in any order of phase rotations of  $360/N$  degrees where  $N$  is an integer.
42. The method of claim 26 wherein the different vibrators are energized by sweeps covering different frequency ranges at different times.
43. The method of claim 26 wherein the different vibrators are energized by sweeps which start at different times.

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44. The method of claim 26 wherein the location of the detectors is selected from the group comprising detectors on the surface of the earth, detectors suspended in the water, detectors on the water bottom, detectors in a wellbore, and a combination thereof.

5 45. The method of claim 26 further comprising:

(a) separating the data from each vibrator into individual records for each source location;

(b) applying static corrections and differential normal move-outs (NMO) to each source location;

10 (c) summing the data for each source location.

45. The method of claim 26 further comprising constructing supergathers to improve the noise separation techniques.

46. The method of claim 26 further comprising separating the data into bins at small common depth point intervals and migrating the data thereby improving  
15 imaging and focusing.